Global Ecology and Conservation 5 (2016) 58–70

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Original research article

A theoretical model of community operated compensation scheme for crop damage by wild herbivores

Watve Milind *, Patel Kajol, Bayani Abhijeet, Patil Pramod

Indian Institute of Science Education and Research (IISER), Dr. Homi Bhabha Road, Pashan, Pune 411008, India

ARTICLE INFO

Article history:
Received 30 September 2015
Received in revised form 23 November 2015
Accepted 24 November 2015
Available online 10 December 2015

Keywords:
Agricultural crops
Human–wildlife conflict
Alternative model of compensation
Game theory
Behavioral economics

ABSTRACT

Damage to agricultural crops by protected species in the vicinity of wildlife parks is an important but underestimated problem. Since measures to protect crops are generally met with limited success in areas with high animal density, some form of compensation for the damage is necessary to avoid resentment of local farmers. The general method of compensation followed globally is that the victim makes a claim, which is verified or negotiated by the compensating agency and the agreed amount is paid. The major flaw in this method is that objective and realistic assessment of damage is difficult. Subjectivity in visual assessment leads to conflicts and both under and over-compensation is counterproductive in the long run. We suggest here an alternative model of compensation, which is based on the net loss in produce, rather than visual estimate of damage. In this model the average loss in net produce is estimated over a belt with comparable risk of damage. The compensation payable is calculated based on the average loss but is paid in proportion to individual farm's produce. Analysis based on principles of behavioral economics shows that this compensation scheme would facilitate good agricultural inputs and honesty in reporting the produce. It would also effectively segregate wildlife damage from other forms of agricultural loss. The theoretical foundation of the alternative model of compensation and suggestive means of implementing it are discussed.

1. Introduction

Damage to agricultural crops by wild animals is a natural phenomenon that presumably existed since the origin of agriculture. However, it is no more possible that this loss is borne by a few farmers close to protected areas without creating resentment, which would be ultimately harmful to conservation (Tchamba, 1996; De Klemm, 1996; Brandon et al., 1998; Terborgh et al., 2002; Gureja et al., 2002; Sethi, 2003; Woodroffe et al., 2005; West et al., 2006; Ogra and Badola, 2008). What was normal, inevitable, and therefore tolerated by people for millennia has now become a source of discriminative justice since wildlife has retracted into small pockets and therefore the menace is also pocketed. Moreover, since more and more species causing crop damage are covered by legal protection, people are prohibited from using methods such as culling.

As resentment in local people is a major potential threat to conservation programs, a number of attempts have been made to mitigate the conflict (e.g. Mathur et al., 2015). Two main possible approaches are either aimed at protecting the crops from damage or to offer direct or indirect compensation for the damage. Although a number of means to repel damaging species including fences, trenches, chemical repellents or scare devices have been tried (Jayson, 1999; Delger et al., 2011), they are rarely effective on a wider scale over a long time (Thouless and Sakwa, 1995; Karanth et al., 2013a,b). Often measures

* Correspondence to: Indian Institute of Science Education and Research (IISER), Homi Bhabha Road, Pune 411008, India. Tel.: +91 20 25908093.
E-mail address: milind@iiserpune.ac.in (M. Watve).

http://dx.doi.org/10.1016/j.gecco.2015.11.012
2351-9894/

that are found effective on a demonstration scale fail when applied landscape-wide for a perceivable reason. Models based on foraging optimization show that when a measure such as a fence or a pheromone repellent is used on a small scale, animals have a choice of avoiding the experimental protected plot and can visit neighboring farms. However, if the measure is applied everywhere, the choice is taken off and animals may start raiding indiscriminately again (Watve et al. Manuscript under review).

Since it is not possible to offer effective protection to crops in every situation, the compensation approach becomes inevitable. The nature of conflict and accordingly the concept of compensation are widespread in wildlife management. However, laws and practices of compensation vary widely across different countries and so does their effectiveness (De Klemm, 1996; Schwerdtner and Gruber, 2007; Gordon, 2009; Agarwala et al., 2010). The cultural and political background often shapes the compensation practices. People's perception and tolerance towards wildlife damage is highly variable across cultures and even locally across a small distance (Agarwala et al., 2010; Nagendra et al., 2010). It is still not a universal practice that a compensation for wildlife damage is paid by the state or public authorities but the number countries offering it appear to be growing (De Klemm, 1996). Compensation by non-governmental organizations (NGOs) with a concern for wildlife is also practiced in some areas (De Klemm, 1996). Currently practiced compensation or insurance schemes have often failed to work satisfactorily due to a variety of reasons the main concern being gross under-compensation (Chen et al., 2013; Karanth et al., 2013a,b).

Among various types of damages caused by wildlife, livestock killing by carnivores has received more attention; compensations schemes appear to work better for such cases since recording and assessment of damage is relatively easier and more objective (Bayani et al. Manuscript under review). Economic loss due to herbivore damage to cultivated plants is much greater in magnitude (Karanth et al., 2013a,b) in most areas but this has received less attention. Most research on crop depredation has focused on mega-herbivores such as elephants (Sukumar, 1991; Bandara and Tischell, 2003). Elephant damage is more conspicuous and therefore easier to detect and assess, whereas damage due to smaller herbivores is rather more diffused and inconspicuous in nature and therefore difficult to assess visually (Sukumar, 1990) although in the long run the losses are significant (Naughton-Treves, 1997). As a result, small herbivore damage remains uncompensated (Ogra and Badola, 2008) or grossly undercompensated (Bayani et al. Manuscript under preparation). The rate of crop loss by herbivores is commonly influenced by factors like distance of the farms from the forest border, herbivore density, cropping patterns, cropping season and other landscape variables (Jayson, 1999; Hegel et al., 2009; Retamosa et al., 2008). Therefore, the nature and extent of conflict is different in different areas (Gordon, 2009).

Compensation procedures in most countries leave the assessment of damage to the personal visual judgment of some authority or are negotiated between the victim and the compensating party. Often there is no correlation between the visible estimate of damage and the actual grain yield (Kear, 1970; Bayani et al. manuscript under review). It is also often difficult to decide whether the damage is caused by the protected species or by something else. Whether compensation will ultimately benefit the conservation cause or not is also debated. Although the general thinking supports the compensation concept (De Klemm, 1996), others think that compensation can be counterproductive in the long run. This fear is based on the assumption that it would encourage human activities in and around the protected areas (Bulte and Rondeau, 2005).

A major deficiency in the field appears to be the lack of development of a sound theoretical platform on which the questions can be addressed (Schwerdtner and Gruber, 2007; Watve et al. manuscript under review). There appear to be few attempts towards developing sound, objective, quantitative and validated methods for the assessment of damage. The social and managerial consequences of under, over or realistic compensation have not been thoroughly examined theoretically and empirically. Effective handling of the problem needs expertise from a multitude of fields including wildlife ecology, agriculture, economics, human behavior and management. A number of problems on the interface of economics and human behavior are addressed by game theory and other economic behavior theories (Neumann and Morgenstern, 1944; Aumann, 2008; Myerson, 1991; Roe, 1996; Henrich et al., 2001). It is possible that a theoretical approach based on principles of human behavior can give us a conceptual solution that can be implemented in different parts of the world appropriately modified to suit the local ecology, agricultural practices, law and culture.

2. Problems in the currently practiced compensation schemes

A universal inadequacy of all the compensation practices is that the laws and procedures all over the world provide no clear cut guidelines on how to estimate damage. Also, there are no reliable methods to differentiate wildlife damage from other sources of damage including domesticated or feral animals. Since there are no objective methods for damage assessment, the system depends upon individual judgments and therefore invites conflicts as well as corruption (Ogra and Badola, 2008; Bayani et al. manuscript under review). It is also important to realize that both under-compensation and overcompensation can have deleterious consequences for conservation. Under-compensation increases resentment and overcompensation can encourage human settlement and activities near the park (Studsrod and Wegge, 1995; Sekhar, 1998; Bulte and Rondeau, 2005). Fears are expressed that inappropriate compensation can even worsen the problem (AFESG, 2007). Therefore, a realistic assessment is extremely important in the long-term interest of conservation.

Farmers with high exposure to herbivore raiding tend to disinvest from intensive agriculture by cutting down the expenditure on quality seed, fertilizer etc. (Bayani et al.; Watve et al. manuscript under review). This decreases the produce qualitatively and quantitatively. Also, they need to spend more resources and efforts in fencing, guarding and other measures of protection. These indirect losses as well as additional costs are not covered by the compensation schemes.

Since almost all procedures involve verification of the damage claims by competent authorities, in areas where the damage frequency is very high, if every incident of damage is to be verified there would be a large requirement of competent personnel and it may become impossible to handle the problem above a certain frequency of damage. If there is a shortage of competent manpower, delay between the instance of damage and site inspection for validation would be inevitable. Since partially damaged plants start regenerating, assessment of damage becomes more and more difficult with increasing delay. The frequency of raids by smaller herbivores with high population density can be very high and a frequency of detectable damage twice a week on a given field is reported (Bayani et al. manuscript under review). At this frequency it might be practically impossible to inspect every instance of damage for verifying the claim.

Your animal syndrome: Indigenous farmers often have a considerable tolerance to wild animals and some extent of damage is accepted as natural (e.g. Hill, 2004; Ogra and Badola, 2008; Campbell-Smith et al., 2010; Canavelli et al., 2013). If the extent of damage is large, farming can no more be sustainable and this may bring in serious resentment. At this stage, it is thought that compensation would reduce the resentment (Sifuna, 2010; Boven-Jones, 2012). Nevertheless, when the park management negotiates for paying the compensation for the damage caused by animals, there is a subtle change in the perception. Animals are no more perceived as a part of nature but as the property of park authorities and a cause of nuisance to farmers. This perceptional change can be damaging to conservation efforts in the long run.

We will examine here whether there can be a model of compensation that can effectively handle most or all of the above problems.

2.1. *Characteristics of an ideal compensation scheme*

The desirable characteristics of an ideal compensation scheme should be the following.

2.1.1. *Fairness*

The compensation package should cover the actual direct and indirect loss due to wildlife but should not overcompensate (Bulte and Rondeau, 2005). For this to happen there should be realistic assessment of damage.

2.1.2. *No free lunch*

The package should encourage farmers' efforts in increasing agricultural productivity as well as in protecting it from damage using non-destructive means. The package benefits should go in proportion to the efforts and alertness of the farmers. If lack of efforts or alertness gets unduly rewarded, the farmer community is likely to become lazy and lose its productivity (Ogra and Badola, 2008). In addition, if the package is too lucrative it will attract outsiders to settle near wildlife parks, which is an undesirable outcome. Therefore, the package should be such that it would not be viewed as free lunch.

2.1.3. *Free from corruption*

The package should not leave any possible ways by which one individual can favor someone and gets bribed for it. The current need of validating damage claim is open for bribe driven favor. If the subjectivity in damage estimation is eliminated, and there are built in validation and crosschecking methods that do not depend upon a single person's judgment or certification, corruption can be arrested.

2.1.4. *Behaviorally sound*

If a system is designed based on the assumption that every individual is selfish, it is likely to work better than a system that assumes honesty or tries to impose it by policing. The design of the system should lead to a situation where "If everyone behaves selfishly there will be honesty and justice!!" If being honest is the most profitable strategy for any individual in the chain, corruption can be completely eliminated.

2.1.5. *Minimum demand on personnel*

The package should require minimal policing, validation and paper work by the park management. If the entire system is based on and operated by the local community, there would be minimum manpower demand on the park management.

2.1.6. *Avoid 'your animal syndrome' and increase local community support to conservation*

The package should avoid the psychological division between the victim and the compensator and the perception that the two have conflicting interests. If conflicts over compensation claims and the need for validation or negotiations are completely eliminated the psychological divide can be substantially reduced.

2.1.7. *Sensitive to changing ecology*

A number of variables including animal population densities, habituation to human presence, preferred crop species, their market values etc. change with time. The system should accommodate these changes naturally without any need to change legislation or implementation procedures.

We will show below that such a dream scheme is possible and easy to implement.

2.2. The proposed package and its implementation

What matters for agricultural economics at any level is the net produce. The proposed package is based on the net harvest per unit area cultivated by a farmer. Since there is poor correlation between visible estimate of vegetative damage and the final grain or such other produce (Kear, 1970; Bayani et al. manuscript under review), it makes sense that the damage is estimated only once at the end of the season by the net produce rather than by looking at the vegetative damaged caused by herbivores from time to time during the season. The scheme is structured in such a way that the maximum benefit of the farmer community is in putting maximum efforts in agriculture and honestly reporting the yield. Both under-reporting and over-reporting of yield will cause a loss to farmers as explained below. Therefore, farmers would report honestly and based on the loss in total yield the due compensation can be calculated by an automated computerized system. The working of the proposed package will go in the following steps.

The conditions under which the scheme can work appropriately are that there is a group of farmers adjoining a protected wildlife area, who grow the same crop and share a comparable risk of depredation. The nature of the risk is such that there is high frequency of raiding with smaller one time damage. This is typically caused by small to medium sized herbivores including deer, antelopes or wild pig (Mehta, 2014). For small herbivores, the frequency of raiding can be high but the damage per raid is relatively small (Bayani et al.; Watve et al. Manuscript under review). In such cases, by statistical principles stochasticity becomes less important and farmers' efforts and alertness are better correlated to the net produce.

For implementation of the scheme, farmers exposed to comparable risks form a cooperative group. Since the risk can be different for different distances (Geisser and Reyer, 2004; Cai et al., 2008; Nath et al., 2015) and across geographic barriers such as rivers, the risk zones will have to be identified using local knowledge. Farmers in one group should belong to the same risk zone. For example, all farms within 1 km of a park can make one zone. 2–3 km may be another zone etc. The local geography and land use pattern needs to be considered while making such zones. Errors in risk level assessment while making such zones can be rectified later as described below. Since all farms in a group share similar levels of risk, the difference in damage would partly reflect the efforts and alertness of the farmer and partly the stochastic elements.

Out of the N farms in a group a random selection of 2–3 farms would be carefully fenced to prevent entry of the protected crop raider species. The nature of fencing will depend upon the damage causing species. The fencing expenditure is borne by the park authority. The fence would have a long life and can be used for many years with some maintenance if and when needed. These farms form the control group which is to be cultivated by the respective farmers with maximum care and intensity. Since these farms are protected from depredation, farmers are expected to have improved motivation for putting greater investment and efforts. Also getting maximum produce from control farms is beneficial for the entire community as described below. Therefore, there will be social pressure on these farmers to give maximum inputs. However, since these farmers are offered good protection, they will not get any other benefits of the compensation package.

All other farmers will leave their farms unfenced but are allowed to guard them by non-destructive means such as shouting, chasing away animals, scare devices etc. but destructive means such as fire arms, traps or poisons will be strictly banned. Such legislation already exists in most areas.

All farmers cultivate their farms through one cropping season. At harvest, the total yield of each farm per unit area is self-reported by each farmer and verified/endorsed by 4 other randomly chosen farmers from the group. The yield in the control farms is measured by the farmer and verified by 4 other randomly chosen farmers and an appropriate park official. The official at the most needs to examine the control plots and 2–3 additional randomly chosen non-fenced farms as a minimum necessary validation. The reported yield on all other farms need not be verified as the system encourages honesty and punishes cheaters as described below.

2.3. Mathematical model

After collecting harvest data from all farms in the group, the compensation is calculated as

X_{avg} = average yield per unit area of fenced control farms.

Y_{avg} = average yield per unit area of unfenced farms.

Y_i = ith farmer's yield.

Compensation for the ith farmer $= \left(\frac{X_{avg}-Y_{avg}}{Y_{avg}}\right) Y_i$.

Compensation may be calculated and paid by to individual farmers by an automated software to avoid any personal favor.

After every 3–5 years the zones can be reorganized according to reported yields. For example if someone consistently reports yields substantially higher than the average for his group he will be shifted to lower risk group and vice-versa.

The implementation of the package can be undertaken by the park management itself or be entrusted to other agencies like cooperative banks or other local organizations that have a money handling infrastructure. All transactions should be done through such organizations so that all records are maintained and data get accumulated in long term.

2.4. Why the model is smart enough to prevent corruption and offer realistic compensation

The compensation package is designed using some of the principles of a mathematical theory in behavioral economics called "game theory". Game theory is a theory of human behavior in the economic context. The theory assumes that every player in a game is selfish and will try to maximize his own benefit (Neumann and Morgenstern, 1944). If a system is designed in such a way that selfishness leads to honesty, such a system can function to be practically corruption free and with no need for policing. Since the compensation is based on the proportionate difference between control and average farms it gives full compensation on the damage on an average. However, it will not encourage laziness, carelessness or deliberate under-reporting of yield for the following reasons.

Those who invest more in agricultural practices and guard better get a better yield and since the compensation is proportionate to individual yields, they will get a greater share of compensation as well. Those who do not invest efforts and care for the crops will get low yield and proportionately lower share of the compensation. Thus, lazy or careless farmers are doubly punished. On the other hand, the requirement for endorsement by other farmers will not allow individual farmers to over-report yield to claim greater share of compensation. Any person showing higher yields reduces the average difference and thereby the total compensation amount. This is against the interest of the entire group. Therefore, the endorsing farmers should not allow anyone to over-report. Because of the conflicting interests of individuals versus the group there will be social pressure on individuals against over-reporting. We will examine below whether the mutually contradicting selfish interests are likely to reinforce honesty in the system and whether any smart selfish strategies can take undue benefits of the system.

2.5. Possible smarter means of defying the system to extract more money

There are 3 potential ways of defying the system but counteracting measures are already built in the system and can be effectively enforced with minimum efforts.

If the control yield is over-reported, everyone will get a greater than due compensation. This can be prevented by appointing an inspecting official of the park whose presence is mandatory for recording the control yield. Even if we assume that the inspecting officer is corrupt and can be bribed, there are multiple additional counter measures. The control yield can be compared to that in the agriculture data collection systems. For example in India there are '*annewari*' or '*paisewari*' records for each district which document the percentage of average agriculture output for each district in a given season (Samra, 2004; NABARD, 2014). In addition, the maximum produce per unit area of any given crop is found in agricultural literature. The control yields cannot exceed these. Therefore, an exaggerated reporting of the control yield can be easily detected. Variation in average yield due to drought or other causes is accounted for in the control. Therefore, these losses will not be covered in the wildlife damage compensation calculation.

Even if we assume that over-reporting the control is possible there are two major hurdles in over-reporting. One is that the control farm owner has no benefit in over-reporting and the other is that the control produce is to be validated by a competent authority. If the validating authority is to be bribed, there is a problem in the stability of this type of bribery. Since the benefit of over-reporting is a community benefit the question is who pays the bribe. Everyone should contribute equally to bribe the inspecting person. However, such a system is open to free riding. An individual that does not contribute can still share the benefit of control over-reporting and therefore such a system is difficult to be stable. Also, since the compensation amount is a function of individual yield, everyone is not benefited to the same extent. Therefore, why should everyone contribute equally to the bribe? It is also not possible to contribute in proportion of the benefit since the benefit gets calculated after the control reporting and therefore the necessary data for proportionate contribution is not present at this time. All these factors make over-reporting of control yield highly unlikely.

If a group of farmers cooperates in such a way that everyone shows a lower yield in the same proportion, for example 20% each, then everyone will be overcompensated. This type of cooperation is inherently unstable because a single individual refusing to do so will get a disproportionately higher benefit, which is sufficient to break down the cooperation. Numerical simulations show (Fig. 1) that when everyone cheats cooperatively by underreporting, the benefit to an honest individual increases exponentially with the extent of underreporting by the community. As the reward for honesty is huge and the benefit of cheating is marginal, cooperative underreporting is unlikely to be stable.

Also verification of just one or a few farms in the entire group by the park authorities is sufficient to break down the cooperative cheating since individuals whose farms have undergone such inspection will be reported factually and thereby will get disproportionately greater compensation. If honesty gives greater benefits, cooperative cheating is unlikely to sustain.

If the community reports honestly and one individual over-reports, he will get a disproportionately higher benefit. However, he will have to get endorsement from 4 other farmers which are members of the group that suffers a loss. For avoiding group loss, which is their individual loss too, the endorsing farmers should prevent over-reporting. In order to get their endorsement, the cheater will have to bribe them with amounts greater than the mean group loss. If the endorsers realize that the benefit to the cheater critically depends on their endorsement they may even demand more. This is an ultimatum game like situation where people are shown to give "fair" offers most frequently (Thaler, 1988). If there are n endorsers, the possible extra profit will be shared amongst $n + 1$ individuals. This leads to two possible situations, in both of which the cheater is at a loss in the long run.

The endorsers demand the bribe in advance, which is a very likely situation. Since at this stage the average yield is not yet calculated, the cheater will have to use an estimated gain of cheating to optimize the bribery amount. However, the endorsers are farmers themselves and once they realize that this trick might increase their compensation too they will try to over-report their yields too by bribing their endorsers. This is a chain reaction by which the average difference will go on reducing so that the actual benefit to the cheater is substantially smaller than the estimated one on which bribery amount was decided. Thus the first cheater is likely to incur a net loss if the bribery amount turns to be greater than the net compensation obtained.

The second option is that the endorsers are only given a promise to share the benefit of cheating after getting the compensation amount. This can save the direct loss to the cheater as above. However, since the bribery is only promised at the time of endorsement, another channel for cheating is opened up in which the promised amount is not given. Even if we ignore this, the chain reaction will continue to operate. As a result a large proportion of farmers will over-report. This over-reporting will blow up the average so that at some stage the numerator in the compensation calculation formula becomes negative. This is a form of automated penalty and it can be seen that at this stage individuals that blow up their yields more will attract greater penalty. Thus although cheating by over-reporting may have short term benefits to individuals, ultimately the system punishes the cheaters proportionate to the extent of cheating.

An additional measure against this type of cheating comes during the periodic rezoning. Individuals that consistently report higher yields or little loss automatically move to the low risk zone during reorganization of zones. Since the average difference in this zone is small, they reduce their benefit in the long run. This is an additional discouragement to over-reporting.

2.6. Optimizing group size

The relationship between individual gain by over-reporting and corresponding group loss is a function of group size (Figs. 1 and 2). Cooperation is easier in a smaller group since individual recognition, reputation and retaliation can play a major role. These cooperation-boosting measures become weaker as the group size increases. Also the reward to an honest defector is smaller in smaller groups. Therefore cheating by cooperative underreporting is more likely in small groups and will be increasingly unstable with larger group sizes. On the other hand, if the group size is large, group loss from a single over-reporting is smaller (Fig. 2(A)). Therefore motivation for the endorsing farmers to prevent over-reporting could be proportionately less. Simultaneously individual over-reporting will be more beneficial with larger group sizes although this increase is in a saturation curve (Fig. 2(B)). As a result the temptation for over-reporting is likely to be more common with increasing group size. Thus, there will be an optimum group size that would minimize cheating of both the types. The precise optimum could vary based upon local conditions including the market value of the crop, extent of damage, cultural norms and the cooperative nature of the society.

3. Characteristics of the model which will fulfill the expectations of an ideal compensation package

3.1. We spelled out in the beginning our expectations from an ideal compensation package

We will examine now whether the proposed scheme promises to fulfils them.

3.1.1. Fairness

Since reporting the produce honestly is the only stable beneficial strategy, realistic reporting is ensured. If the reporting is realistic, the compensation covers the entire loss on an average. One possible objection to the compensation formula is that if the difference in losses between farms is due to different raiding risks then the once raided more will get lesser yield as well as lesser compensation. We assume in the model that variation in loss within a group is stochastic and therefore will average out eventually. For smaller herbivores with high frequency and small damage per visit, this is most likely to happen within a given season itself. For larger herbivores effective averaging might happen over a few seasons. If the variation in damage is non-random and some farms are genuinely at a higher risk, they would consistently show departure from the average based on which they would get regrouped during the periodic rezoning. As they are shifted to the high risk groups their compensation will increase automatically. Therefore in the long run the system offers justice to all.

3.1.2. No free lunch

The proposed scheme is unlikely to make the farmers lazy and disinvest from agriculture. Uncertainty in returns is a strong discouragement in investment and efforts in agriculture (Watve et al. Manuscript under review). With realistic compensation the uncertainty would be reduced substantially and the farmers would have a greater motivation to increase the investment and efforts. Also since the compensation is directly proportional to individual produce, there is a direct reward for greater investment and efforts. Therefore we expect the farming efforts to go up rather than go down with this compensation package.

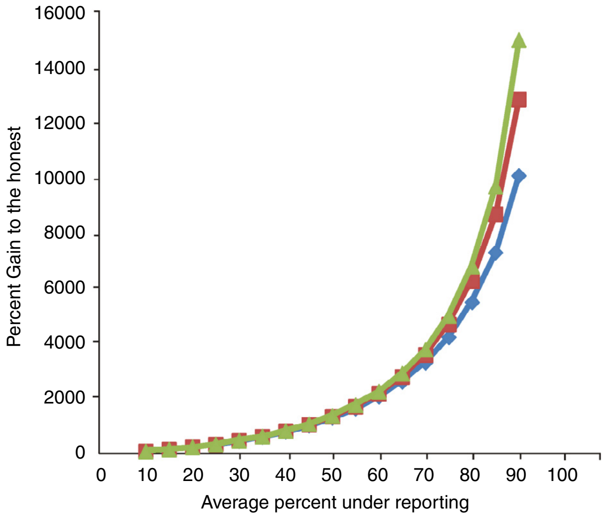

Fig. 1. The benefits of honesty in a cooperatively underreporting group: Numerical simulations with group sizes 25 (blue), 50 (red), and 100 (green) and mean damage 50% show that an honest defector gets disproportionately large rewards that increase exponentially with the extent of underreporting. The reward increases with group size. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.1.3. Free from corruption

We have discussed above the possible ways of getting undue benefit by bribing someone and how all these ways are inherently unsustainable. Therefore we do not see any scope for corruption in the system.

3.1.4. Behaviorally sound

The system is designed based on the assumption that every individual is selfish. Since maximum long term selfishness lies in honesty, there is little need for policing to ensure smooth running of the system.

3.1.5. Minimum demand on personnel

It follows from the above statement that if the need for policing and verification is brought to a minimum the personnel demand on the management also comes down to a minimum.

3.1.6. Avoiding your animal syndrome

The compensation package is based on community self-reporting and deriving the benefits from an automated smoothly operating system with no face to face conflict or negotiations. This is likely to increase harmony and reduce the psychological divide between the victims of damage and the compensators. Human–wildlife conflict may give way to human–wildlife coexistence since the severity of conflict is expected to reduce substantially.

3.1.7. Sensitive to changing ecology

Changes in predominant crop species and their market values are accommodated in the calculations naturally. The risk zones can change with animal populations and their habituation and other behavioral changes. This can be taken care of during rezoning. Since the rezoning can be based on past few years' yield records, subjectivity can be minimized or eliminated from the rezoning procedure. Thus the main expected ecological changes can be easily accommodated in the system.

3.2. Other possible advantages of the compensation scheme

3.2.1

If the proposed scheme is implemented for and restricted to areas with a park status, farmers where there is significant animal population and therefore substantial crop damage will demand a park status on their own. At least the resistance of local people to park status, which is common in many areas, would reduce considerably (Badola, 1998; Vijayan and Pati, 2002; Ogra and Badola, 2008; Karanth et al., 2012).

3.2.2

In the proposed scheme damage estimation and its validation is intrinsically reliable. Therefore reliable data will keep on accumulating automatically.

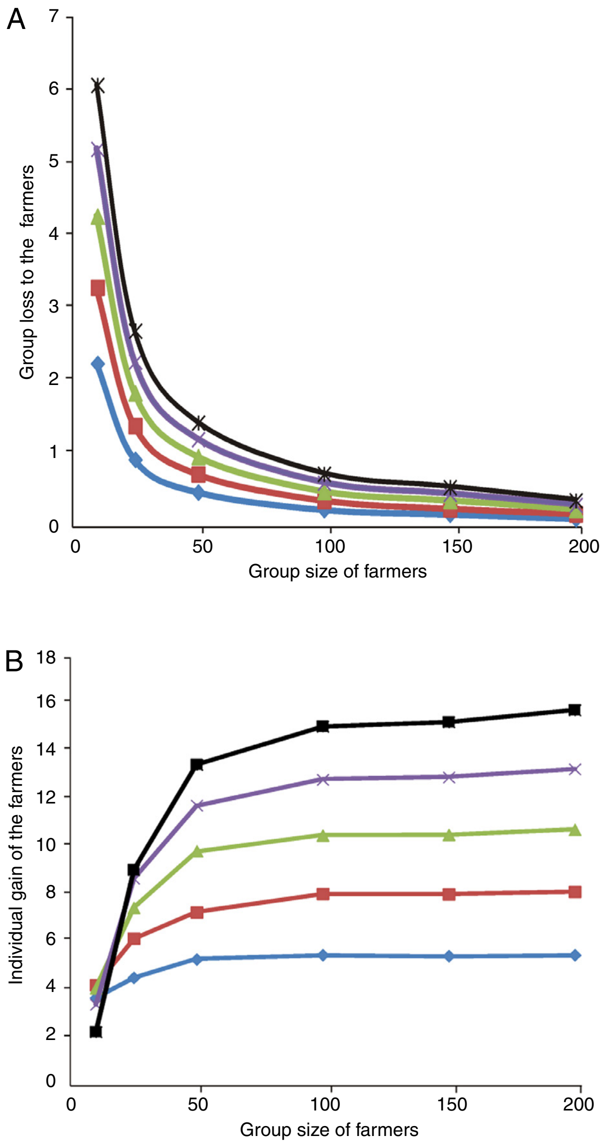

Fig. 2. Effects of individual over-reporting with varying group sizes: Results of numerical simulations with mean loss of 50%. Different curves show different extent of over-reporting expressed as percentage of actual yield. (A) Curve showing decrease in group loss with increase in group size at different percent of over-reporting (10 (blue), 15 (red), 20 (green), 25 (violet), 30 (black)) (B) Curve showing increase in individual gain of the over-reporter with group size. (10 (blue), 15 (red), 20 (green), 25 (violet), 30 (black)). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.2.3

In some areas wild animals are at least partially dependent on the crops for nutrition (Jhala, 1993; Chiyo et al., 2011; Mehta, 2014). The proposed scheme does not exclude animals from crop raiding and people's tolerance is expected to increase which would benefit wild herbivores, particularly Rare Endangered and Threatened (RET) species.

The scheme will exert a large financial burden on the park management. However it should be realized that this is the realistic cost of maintaining parks which was being overlooked so far. Although the cost would be high, since the package is expected to mobilize greater support from local people, policing for protection may become much less important. Poachers' support base among unhappy local people is likely to deteriorate rapidly which would ultimately serve the conservation purpose better.

3.3. Conditions where the system may fail to work

We also need to identify conditions under which the system may fail to work and is therefore not recommended.

3.3.1

For animals such as elephants where individual farmers would be unable to drive away the raiding animals and doing so is risky too (Nepal and Weber, 1995).

3.3.2

If the frequency of raiding is low but the damage in one night is large, which is typical of large animals such as elephants (Sukumar, 1990), the scheme may suffer from serious statistical problems where stochasticity rather than farmer's alertness will be the major determinant of the total damage. In such cases averaging out of the damage is much more difficult and there would be injustice to some of the farmers.

3.3.3

The system is based on the assumption that individual farmers are free to take decisions and maximize their net benefits. If in any area individual decisions are under pressure due to terrorism, non-democratic political dominance and such factors, the system cannot ensure fairness. If a powerful landlord or a dominant lobby can coercively manipulate farmers, the system can be taken for a ride by the power holders (Ogra and Badola, 2008). In a democratically run social organization with sufficient individual freedom the system can run in its full efficiency.

In an era where the pros and cons of the two philosophies of conservation namely people's displacement and enforced protection versus community based conservation are being debated (Zhang and Wang, 2003; Berkes, 2007; Agrawal and Gibson, 2001), a community operated system of justice such as the one suggested here is likely to bring harmony and peaceful coexistence of people and wildlife.

4. Example application to real life data

We studied quantitative patterns of crop damage by wild herbivores on the western boundary of Tadoba-Andhari Tiger Reserve in central India the details of which are being published elsewhere (Bayani et al. manuscript under review). The need for alternative compensation scheme was realized during this study when we found that the compensation currently being paid is a tiny fraction of the actual loss estimated using six different approaches for damage assessment. We will illustrate here the calculation of compensation based on that data using the principles above and contrast it with the compensations actually paid to farmers in the area in the same season. The data on yields of rice and wheat comes from fields lying along three transect lines radiating from the park boundary. In this area the ecotone is rather sharp and there is no forest cover on the western side of the park boundary. Therefore the risk linearly decreases with distance along the transect lines going away from the park boundary. We take the first one kilometer on the transect lines to represent a comparable risk zone as suggested by the transect data.

In 2013–14 and 2014–15 an experimental comparison of yields in neighboring fenced and non-fenced (and non-guarded) areas was done as one of the methods of assessing the extent of damage. Data from the fenced area can be used as the protected control (X_{avg}) of our model. Although the group size in this example is rather small, it can be used to illustrate the difference the proposed scheme makes. Fig. 3 illustrates the frequency distribution of normalized per Hectare yields of farms in the sample along with the protected and unprotected controls for Rice in kharif season of 2013 and wheat in rabi seasons of 2013–14 and 2014–15. Rice in 2014 was badly affected by untimely rains followed by a disease therefore data for this year was not available. The following rabi was a bad season for wheat also but the crop did not fail completely. The calculations show that this loss is automatically discounted in the compensation calculation so that compensation becomes specific for herbivory damage. For all the three sets of results it can be noted that the unprotected control that was neither fenced nor guarded yielded the minimum. In the case of wheat in both seasons the unprotected farms were completely devoured. In the case of rice the unprotected control yielded non-zero amount and there were one or two farms with yields less than it. All farms by farmers who actively did night time guarding had yields somewhere between the protected and unprotected controls except two that were marginally above the protected control. This finding is compatible with the model assumption that yield is a function of guarding efforts. The calculated damage compensations are as follows (all in quintal per hectare i.e. Q/Ha). For rice in 2013, the control yielded 26.07 Q/Ha and the average for 9 other farms was 15.67 Q/Ha, as a result the percent compensation was calculated to be 66.33% over each farmer's yield. By the current market value the average compensation due per farmer was ₹17,523. For wheat in 2013–14 the protected control yielded 24.88 Q/Ha, the average of 13 others was 3.99 Q/Ha indicating substantial loss. As a result the percentage compensation due was 523.5% and the average compensation due per farmers was ₹40,349. In 2014–15 wheat yield was lower throughout the area when the protected control yielded 16.48 Q/Ha, the average was 1.25 Q/Ha so that the percent compensation due was 1218.4%. Interestingly, in spite of every farmer's yield being lower and the percent compensation due being higher, the average compensation due per farmer was substantially lower than the previous year (₹23,260). This is because the main reason of crop loss this year was more climatic than herbivore related. This illustrates that the scheme could differentiate between different causes of loss and specifically focuses on herbivore loss. The average compensation per farmer calculated for all the three crop seasons contrasts with the amounts actually paid by the government to farmers in these two year in the entire buffer zone of TATR. Only a small proportion of farmers (estimated at $<1\%$) were paid compensation and among those that were paid, the average

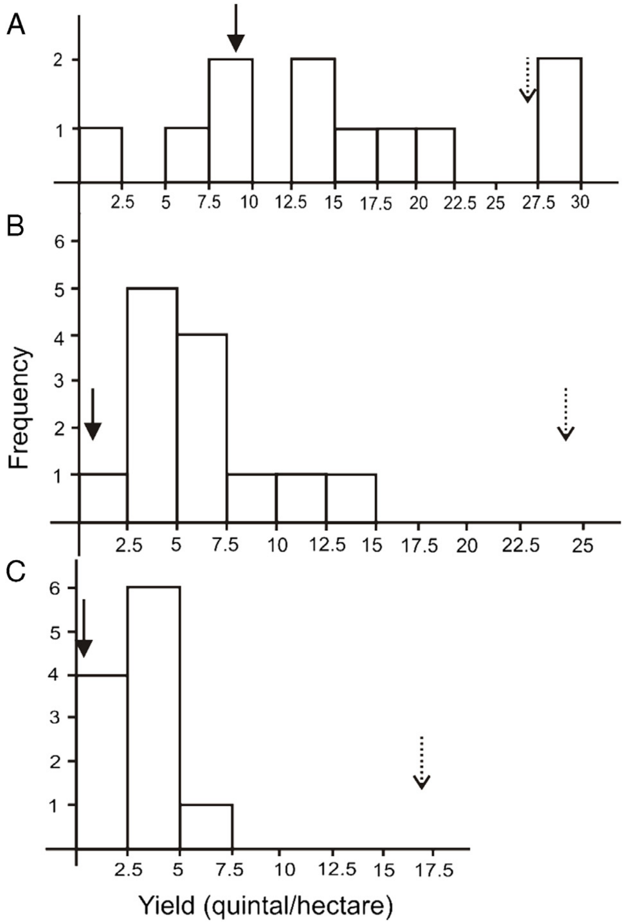

Fig. 3. The frequency distribution of farmers' yield in comparison with protected (dotted arrows) and unprotected controls (solid arrows): (A) Rice in 2013; (B) Wheat in 2013–14 and (C) Wheat in 2014–15. All yields expressed as Q/Ha.

per farmer was ₹4244. This is compatible with the inference of the study (Bayani et al. manuscript under review) that the current compensation scheme grossly underestimates damage.

The above data on yield was collected from farmers who were not aware of the compensation scheme suggested by us. Therefore they are unlikely to have manipulated the yields for increasing their gains. Also about one fourth of the claimed yield was verified by research personnel on inspection based on the count of bags or the market price actually obtained.

5. Test of honesty in a simulated game

In order to test whether self-reporting of yield along with endorsement of others in the group ensures honesty, a simulated compensation game was played in three groups of subjects with 46, 29 and 27 individuals. The former two groups were university students and the last one was in a club mainly attended by businessmen and executives. The participants were asked to imagine themselves in the farmer's role and the rules of the game as defined earlier were explained to the group before starting the game. They were also told to play towards maximizing their benefit. During the game each player was given a number in a closed envelope to represent a yield. The person had to report his yield to the game organizers who did not have access to the actual yield assigned to that individual. However the number reported by each player was to be endorsed by two neighbors who had the right to demand access to the enveloped yield of that player. After everyone's report the data were compiled and awards of each player calculated. The game was repeated 5 times successively each time randomizing each individuals yield keeping the average yield unchanged.

Fig. 4 shows the results of behavioral outcomes. In the two student groups initially there was large variance in honesty as well as an overall under or over-reporting bias. But within 2–3 trials it vanished and honesty prevailed. In the group dominated by businessmen and executives, honesty prevailed right from the first trial and the variance was low throughout. This may not suggest that businessmen are more honest by nature, but it suggests that if the financial implications are

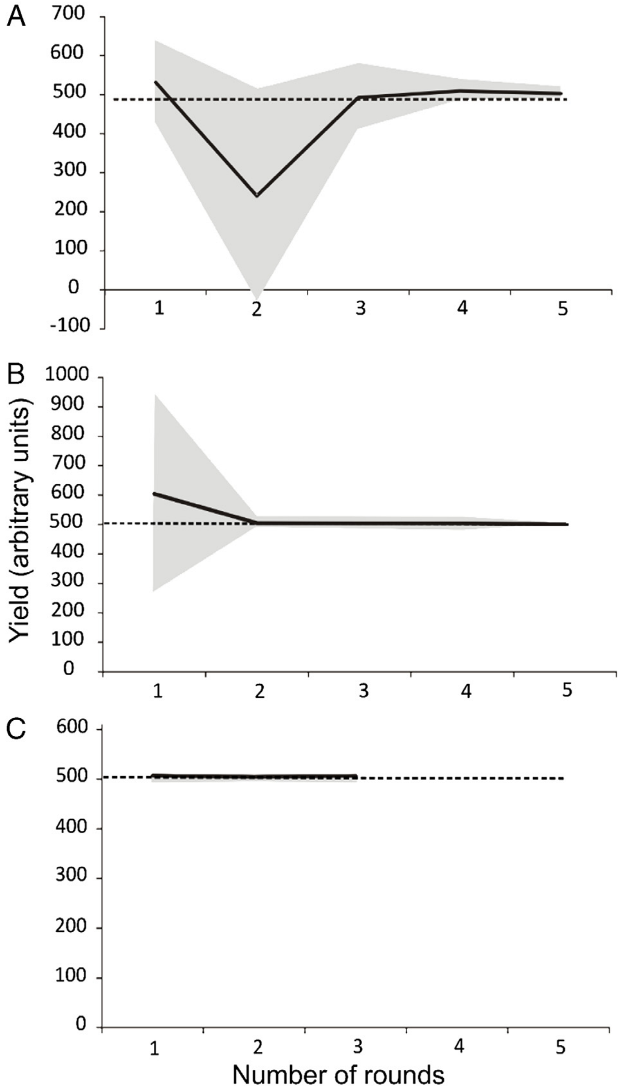

Fig. 4. Trends in honesty in compensation game: The game was played in 3 groups ((A), (B) and (C) respectively) for 5 independent repeats. The black line represents the mean of all reported yields which converges to the true mean (dotted line) with subsequent repeats. The shaded area represents the standard deviation caused by dishonesty. Variance around the mean reported yields is contributed by the variance in the given enveloped yields and the dishonesty in reporting. If the former is known, the latter can be calculated even without having access to the differences between actual and reported numbers. Convergence of the reported mean to true mean and reduction of standard deviation indicated increasing honesty with experience. In group 3 honesty was displayed from the very first attempt and was consistent over the next two repeats and therefore the game was terminated.

understood better, honesty prevails. What the student groups appeared to learn in 2–3 trials, the business and executive group could foresee. Interestingly the right to see the enveloped number was not always used by the players for endorsing someone else's report. Perhaps the existence of that facility was sufficient to reinforce honesty.

Ideally this game should be played with farmers actually affected by the problems and also it should be played with real money rewards involved. However, it might be counterproductive to do this with farmers if the game trial is not followed by actual launching of the compensation scheme. It is likely that the game would increase their expectations and if they are not fulfilled the resentment can increase further.

Ideally the steps towards implementing such a scheme should be (i) a theoretical academic exercise to analyze any possible flaws and improvements in the scheme (ii) larger scale game trials with actual money involved on groups with varied cultural and educational background (iii) to run a trial implementation in one or a few conflict areas (iv) incorporate improvements, if any, suggested by the trial and (v) scale up to implement on a wider scale. Progression along these steps should be guided by successes in earlier steps. Experience could suggest subtle improvements in the detailed protocol. However in case of a convincing failure, one needs to be open to give up. Owing to complexities of real life, it is a good strategy to scale up any conservation measure stepwise, carefully monitoring every necessary parameter.

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